http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

VARIATION ON MAIZE GREEN EARS AND GRAIN YIELD IN RESPONSE TO WEED COMPETITION[1]

PAULO SÉRGIO LIMA E SILVA[2], ANTONIO EDILBERTO DE SOUSA[3] , JORGE KLEBER DE OLIVEIRA GOMES[3] e JÚLIO CÉSAR DO VALE SILVA[4]

[1]The present paper was carried through with the support of the National Counsel of Technological and Scientific Development (CNPq), Brazil
[2]Professor, Universidade Federal Rural do Semi-Árido (UFERSA). Caixa Postal 137, CEP 59625-900 Mossoró, RN, Brazil. E-mail: paulosergio@ufersa.edu.br (corresponding author).
[3]Estudante do curso de Mestrado em Fitotecnia da UFERSA. Caixa Postal 137, CEP 59625-900 Mossoró, RN, Brazil.
[4]Estudante de Agronomia da UFERSA. Caixa Postal 137, CEP 59625-900 Mossoró, RN, Brazil.

Revista Brasileira de Milho e Sorgo, v.6, n.1, p.74-83, 2007

ABSTRACT - The objective of this study was to verify whether maize cultivars behave differently, in competition with weeds, to produce green ears and grain. Randomized complete block design was used, with split-plots and five replications. Cultivars AG 405, AG 2060, BA 8517, BA 9513, DKB 435 and EX 6005, applied to the plots, underwent the following treatments: without weeding and two weedings (22 and 41 days after planting). Only ten weed species were found in the experiment, many of which were gramineae. There was no difference among cultivars in relation to the number of weeds m^{-2}. The number of weeds in the weeded plots (70.0 m^{-2}) was superior to the one of the no-weeded plots (32.8 m^{-2}). The cultivars only differed in grain yield when the weeds were controlled, with BA 8517 cultivar standing out as being superior. Therefore, the cultivars presented different reductions in grain yield with the presence of weeds suggesting that some (AG 405, BA 9513 and EX 6005) are more competitive than others against weeds. The weeds reduced green ears yield, in addition to 16 of the 26 evaluated characteristics, including some traits of the stalk, leaves, tassel, ear and grain.

Key words: *Zea mays*, green ears yield, green corn, grain yield.

VARIAÇÃO NA PRODUÇÃO DE ESPIGAS VERDES E GRÃOS DE MILHO EM RESPOSTA A COMPETIÇÃO COM PLANTAS DANINHAS

RESUMO - O objetivo deste estudo foi verificar se cultivares de milho comportam-se diferentemente, em competição com plantas daninhas, para produzir espigas verdes e grãos. Utilizou-se o delineamento de blocos ao acaso, com parcelas subdivididas e cinco repetições. As cultivares AG 405, AG 2060, BA 8517, BA 9513, DKB 435 e EX6005, aplicadas às parcelas, foram submetidas aos seguintes tratamentos: sem capinas e duas capinas (aos 22 e 41 dias após o plantio). Somente dez espécies de plantas daninhas ocorreram no experimento, sendo gramíneas a maioria delas. Não existiram diferenças entre cultivares quanto ao número de plantas daninhas m^{-2}. O número de plantas daninhas nas parcelas não-capinadas (70,0 m^{-2}) foi superior ao das parcelas capinadas (32,8 m^{-2}). As cultivares somente diferiram quanto ao rendimento de grãos quando as plantas daninhas foram controladas, com a cultivar BA 8517 destacando-se como superior. Por-

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

tanto, as cultivares apresentaram diferentes reduções no rendimento de grãos, com a presença de plantas daninhas, sugerindo que algumas (AG 405, BA 9513 e EX 6005) são mais competitivas que outras contra as plantas daninhas. As plantas daninhas reduziram o rendimento de espigas verdes, além de 16 das 26 características avaliadas, incluindo algumas características do caule, folhas, pendão, espiga e grão.

Palavras-chave: *Zea mays*, rendimento de espigas verdes, milho verde, rendimento de grãos.

The need to reduce herbicide applications to protect the environment slow the development of herbicide resistance evolution in weeds, and reduce growing costs has renewed interest in improving crop cultivar interference with weed growth (Pester *et al*., 1999).

Weed competitiveness of crops has two components: weed tolerance, i.e., the ability to maintain high yields despite weed competition, and weed suppressive ability, i.e., the ability to reduce growth through competition (Jannink *et al*., 2000). Crops with increased competitiveness may be more effective in weed suppression, tolerate interference better, or both (Jordan, 1993). Such cultivars would be particularly useful for reducing hand weeding requirements in labor-limited systems where weed competition is a serious constraint. Improving cultivar competitiveness is an attractive weed management strategy because it is low cost, useful low and high-input cropping systems, and, once available, improved cultivars are easily delivered to and used by farmers (Caton *et al.,* 2003).

Varietal differences in suppression capacity of weeds were reported for several crops, including maize (Begna *et al*., 2001). Tollenaar *et al.* (1994) verified that with a large incidence of weeds and a high nitrogen level, a "modern" hybrid of maize demonstrated less average yield loss (11%) than an older hybrid (17%). The greater yield losses of the older hybrid, in two nitrogen levels, were attributed to less efficiency in nitrogen use and the differences between the hybrids in leaf area index (LAI) and photosynthetic photon flux density.

Plant height, leaf development rate, LAI, and crown leaf distribution are among the most important characteristics in the competition for light (Sinoquet and Caldwell, 1995). Characteristics such as these can be improved through crop practices, such as changing the spacing or plant density, and/or plant breeding (Lindquist & Mortensen, 1998). These approaches can help maize plants compete better with weeds and help farmers to reduce herbicide quantities required to control the weeds, and consequently, reduce environmental damage (Begna *et al*. 2001).

The objective of this study was to verify whether maize cultivars behave differently in competition with weeds to produce grain and green ears.

Material and Methods

The experiment was carried out at the "Rafael Fernandes" Experimental Farm at the Universidade Federal Rural do Semi-Árido (UFERSA), 20 km from the county seat, Mossoró-RN, Brazil (5º' latitude, 37º 20' WGr longitude and an altitude of 18 m), with sprinkler irrigation. According to Gaussen's bioclimatic classification, the climate in the Mossoró region is of the 4ath type, that is, distinctly xerothermic, which means hot tropical and accentuated drought, with a long 7 to 8 month season and a xerother-

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

mic index between 150 and 200. According to Köppen, the region's bioclimate is BSwh, that is, hot, with greater precipitation delaying into the autumn. The region has an average minimum air temperature ranging between 21.3 and 23.7º C and an average maximum between 32.1 and 34.5º C, with June and July as the coolest months, and average annual precipitation of around 825 mm (Carmo Filho & Oliveira, 1989).

The experimental soil, classified according to the Brazilian Soil Classification System as Argissolo Vermelho-Amarelo Eutrófico (Sistema, 1999) and as Ferric Lixisol according to the Soil Map of the World (FAO, 1988), was prepared with two plowings and fertilized with 30 kg ha^{-1} of N (urea), 60 kg ha^{-1} of P_2O_5 (simple superphosphate) and 30 kg ha^{-1} of K_2O (potassium chloride). The fertilizers were placed in furrows located alongside and below the sowing furrows. The analysis of a sample of the experimental soil indicated: pH = 6.8; P = 25.0 mg dm^{-3}; $K^+ = 0.10$ $cmol_c\ dm^{-3}$; $Ca^{2+} = 1.80$ $cmol_c\ dm^{-3}$; $Mg^{2+} = 0.40$ $cmol_c\ dm^{-3}$; $Al^{3+} = 0.00$ $cmol_c\ dm^{-3}$; $Na^+ = 0.01$ $cmol_c\ dm^{-3}$ and organic matter = 1.90 g kg^{-1}.

Sowing was made on 3/21/2004, using four seeds per hole. Spacing of 1.0 m was used between rows and the holes in the same row were spaced at 0.4 m. The thinning was carried out on the 17th day, leaving the two strongest plants in each hole. Therefore, after thinning, the experiment had a programmed planting density of 50 thousand plants/ha. Deltamethrin (250 ml/ha) was sprayed on the crop 12 days after sowing to control the "fall armyworm" (*Spodoptera frugiperda* Smith), the crop's main pest in the region. On days 22 and 41 sidedressing fertilizations were done using 30 kg/ha (urea).

Randomized complete block design was used, with split-plots and five replications. Each experimental unit consisted of four rows measuring 6.0 m in length each. The useful area was considered to be the area occupied by the two 5.2 m central rows. Cultivars AG 405, AG 2060, BA 8517, BA 9513, DKB 435, and EX 6005, applied to the plots, underwent the following treatments: without weeding and two weedings (22 and 41 days after planting). The weedings were performed with a hoe, and the same employee was designated to carry out the job in each block.

The following variables were evaluated in maize plants, based on randomized samplings obtained from the central rows of each plot: (a) plant height = distance from the soil level up to the highest leaf insertion; and ear insertion height = distance from the soil level up to the highest ear insertion (both measured in ten plants, at the harvest time of dry plants); (b) internodes' number, length and diameter (from three plants); (c) leaf length, width and area (evaluated in the upper seven leaves of three plants after the harvest of green ears); (d) tassels' branch number, length and dry biomass (from three plants); (e) green ear yield (green ears from one central row); (f) grain yield (grain humidity corrected for 15.5% humidity) and number of ears, determined from mature ears from one central row, and estimated for one hectare based on the useful subplot area; (f) number of grains per ear; number of grain-rows per ear; ear and cob diameter (from a ten-ear sample); 100-grain weight (ten samples of 100 g); grain width, height, and thickness (from 20 grains sample). The tassel dry biomass was obtained after sample drying in a forced-air oven at 75ºC until constant mass. Leaf area was evaluated using a leaf area meter LI 3100 (LI-COR Inc.). Leaf length and width, and internodes' length were measured using a ruler; internodes' diameter was determined with a digital caliper.

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

At 100 days after sowing the composition of the weeds present in the experiment was evaluated. The weeds were collected, by cutting them even with the soil, and counted in two areas randomly chosen in the useful area of each plot delimited by an 0.5 m x 0.5 m wooden frame.

The soil was prepared using a tractor, the sprayings were carried out with a backpack sprayer and the other operations were done manually.

The data were analyzed statistically using the analysis of variance method (Zar, 1999). The number of weeds m^{-2} that occurred in the experimental area were transformed to before analysis of variance.

Results and Discussion

Only ten weed species were found in the experiment, many of which were gramineae: *Alternanthera ficoidea* (L.) P. Beauv. (Amaranthaceae); *Borreria verticilata* (L.) G.F.W. Meyer. (Rubiaceae); *Cenchrus echinatus* L. (Gramineae); *Commelina sp*. L. (Commelinaceae); *Cucumis anguria* L. (Cucurbitaceae); *Dactyloctenium* (L.) Beauv. (Gramineae); *Digitaria sanguinalis* (L.) Scop. (Gramineae); *Melochia pyramidata* L. (Sterculiaceae); *Phyllanthus niruri* L. (Euphorbiaceae) and *Senna uniflora* (P.Mill) Irwin &Barneby (Leguminosae).

This low number of species might probably be associated to the intensive maize cropping in the area during the last ten years (two cultivations per year involving disk leveling and fertilization). Usually the weed biomass production, as well as the plant diversity and density are lower in the conventional cultivation (intensive soil preparation and high rates of agrochemicals), intermediary in the minimum tillage system, and higher in the organic system (Menalled *et al*., 2001). The weed population in a specific area depends on several factors and although such population is composed of different species, some few usually dominate, corresponding to 70 % - 90 % of the total species (Buhler, 1999). There was no difference among cultivars in relation to the number of weeds m^{-2}.

There was no cultivar effect as to: internode diameter (CVa = 9 %), plant height (CVa = 13 %), and ear height (CVa = 8 %), weight of green ears with husk (CVa = 17 %), grain width (CVa = 3 %), grain thickness (CVa = 3 %), and grain height (CVa = 11 %). There was no weed control effect on the internode number (CVb = 12.6 %), internode length (CVb = 7 %), and the tassel length (CVb = 8 %). There was no cultivar and weed control effect on the length of tassel branches (average of 20.1 cm, CVa = 9 %, and CVb = 11 %), length of green ears with husks (average of 28.1 cm, CVa = 22 %, and CVb = 19 %) and unhusked ear (average of 17.9 cm, CVa = 20 %, and CVb = 19 %), total number of green ears (average of 47,853 ears ha^{-1}, CVa = 9 %, and CVb = 9 %), and number of mature ears (average of 47,834 ears ha^{-1}, CVa = 6 % and CVb = 7 %). The interaction between cultivars and weed controls only occurred in grain yield. Thus, for the other characteristics only the main effects from the two treatment groups will be presented (Tables 2 and 3).

The cultivars only differed in grain yield when the weeds were controlled, with BA 8517 standing out as being superior (Table 2). Therefore, the cultivars presented different reductions in grain yields with the presence of weeds suggesting that some (AG 405, BA 9513, and EX 6005) are more tolerant than others to weeds. Similar observations were reported by other authors (Ford & Pleasant, 1994; Begna *et al*., 2001; Gomes, 2005). The interactions between maize cultivar and weed plants will depend on the seasonal year, which will affect weed plant population (Ford & Pleasant, 1994). The superiority of some maize hybrids in the presence of weeds might not be due to their ability to reduce weed growth through better plant architecture or higher water and nutrient competition, but to their higher ability to maintain grain production in the presence of high weed incidence (Ford & Pleasant, 1994). The cultivars vs. weed control interaction was detected only in the grain yield for some causes. For example, it did not occur in the components of the grain yield and in the green ears yield. Different characteristics are obviously evaluated with different precisions. Green ears and grain are differently-exploited products. Ears considered worthless as green corn can be perfectly used when the goal is to produce dry grain. Besides, the green ears are harvested at least 20 days before of the mature ears harvest. Thus, the harmful effect of the weeds would be bigger on the grain yield than in the green ears yield.

The yield differences among cultivars were due to the differences in the number of grains ear^{-1} and the weight of 100 grains, so long as they did not differ as to the other production component (number of ears ha^{-1}). Although they did not differ in 100-grain weight**,** the **cultivars** did not differ in grain dimensions. One possible explanation for this is that these measurements were evaluated in their maximum dimensions. For example, grain width was measured at the widest part of the grain. It is probable that the cultivars will differ in these terms if the grain width is measured at another point of the grain. The fact that the cultivars differ as to the number of rows of grain in the ear (table 1) supports this idea. Although the cultivars have behaved differently in relation to weed control, they did not

TABLE 1. Means for traits of maize cultivars with and without weeding[1]

Cultivars	**Internodes**		**Tassel**			**Number of grains ear $^{-1}$**
	Number plant^{-1}	**Length (cm)**	**Length (cm)**	**Branches number**	**Dry biomass (g tassel^{-1})**	
AG 405	12.3 b	15.7 a	51.5 a	13.7 a	11.3 ab	337.8 b
AG 2060	12.5 ab	13.6 b	47.9 ab	11.2 b	11.2 ab	374.3 ab
BA 8517	12.6 ab	14.6 ab	44.5 b	9.8 b	11.4 ab	338.1 b
BA 9513	13.2 a	14.4 ab	47.8 ab	11.3 b	10.7 ab	352.8 ab
DKB 435	12.7 ab	14.1 ab	51.7 a	13.9 a	13.0 a	403.0 a
EX 6005	12.4 ab	14.3 ab	44.5 b	9.4 b	9.2 b	344.2 b
CVa, %	5	10	8	15	14	11

Cultivars	**Grain yield (kg ha^{-1})**		**100-grain weight (g)**	**Mature ears**		**Cob diameter (cm)**
	Two weedings			**Diameter (cm)**	**Number of grain row ear^{-1}**	
	With	**Without**				
AG 405	4375 abA	4092 aA	28.6 ab	4.18 c	13.7 c	2.36 b
AG 2060	5189 abA	3719 aB	26.9 bc	4.61 a	15.2 a	2.64 a
BA 8517	5603 aA	4073 aB	30.6 a	4.54 ab	14.1 b	2.41 b
BA 9513	4973 abA	4558 aA	29.2 ab	4.61 a	14.3 ab	2.47 b
DKB 435	5411 abA	4307 aB	24.8 c	4.26 c	14.1 b	2.48 b
EX 6005	4176 bA	3624 aA	28.7 ab	4.36 bc	13.4 b	2.40 b
CVa, %	19		7	3	5	6

[1] Means followed by the same letters, small letters in the columns and capital in the lines, do not differ by Tukey's test ($P < 0.05$).

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

differ as to the characteristics considered important in competition with weeds, such as plant height and leaf characteristics (Sinoquet & Caldwell, 1995). It is also true that there were differences among cultivars in terms of internode number and internode length (Table 1) indicating differences in the number and possibly arrangement and total area of leaves. The cultivars that presented the greatest number of internodes were not those that presented the greatest internode length, which explains the absence of differences among cultivars with regard to plant height and ear height (Table 1).

Weeds reduced 18 of the 26 evaluated characteristics, including those involving the stalk, leaves, tassel, ear, and grain (Table 2). Reductions in corn leaf area (Aflakpui *et al*., 2002), plant height (Begna *et al.,* 2001), green ear yield (Silva *et al*., 2004a), grain yield (Silva *et al.,* 2004b) and other traits (Gomes, 2005) caused by weeds were also observed by other authors**.**

The weeds reduce crop yield by competing with them for water, nutrients and light (Carruthers *et al.,* 1998). The removal of nutrients by weeds has an impact on nutrient availability for the crop, thus affecting its accumulation of dry matter (Sreenivas & Satyanarayana, 1996). Actually, N absorption by weeds can vary from 32.4 kg ha^{-1} to 52.3 kg ha^{-1}, depending on the type of control; in the case of P_2O_5, the variation was 4.3 kg ha^{-1} to 7.2 kg ha^{-1} and in the case of K_2O, from 32.1 kg ha^{-1} to 38.9 kg ha^{-1}. Nitrogen deficiency symptoms develop earlier in corn infested with weeds than in corn that has been cleared of weeds, which implies N depletion in the soil with corn planted with weeds (Rajcan & Swanton,

TABLE 2. Means for traits of six maize cultivars evaluated with and without weddings.

Evaluated traits	**Two weeddings**		**CVb, %**
	With	**Without**	
Internode diameter(cm)	1.24 a	1.13 b	9
Plant height (cm)	191 a	186 b	4
Number of tassel branches	12.6 a	10.6 b	13
Tassel dry biomass (g tassel^{-1})	12.3 a	10.0 b	28
Mean of leaf length (the upper seven leaves) (cm)	69.7 a	63.6 b	9
Mean of leaf width (the upper seven leaves) (cm)	7.5 a	6.9 b	9
Total leaf area (the upper seven leaves) (cm^2)	2378 a	1937 b	18
Green ears with husks (kg ha^{-1})	11,046 a	8,806 b	12
Number of grains ear^{-1}	381.2 a	335.5 b	9
100-grain weight (g)	28.8 a	27.6 b	6
Number of husks ear $^{-1}$	12.8 a	12.3 b	6
Ear diameter with husks (cm)	4.49 a	4.37 b	3
Cob diameter (cm)	2.51 a	2.41 b	5
Number of grain row ear^{-1}	14.2 a	13.7 b	5
Grain width (mm)	7.98 a	7.85 b	2
Grain thickness (mm)	4.15 a	4.10 b	3
Grain height (mm)	10.54 a	9.56 b	12

[1]Means followed by the same letters in the line do not differ by Tukey's test ($P < 0.05$).

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

2001). Furthermore, reductions in corn yield are less with high doses of nitrogen than with small doses (Tollenaar *et al*., 1997). But another aspect must be involved.

The corn root system is less developed with weed presence (Thomas and Allison, 1975). Thus, a smaller corn root system due to weed presence would be less efficient in nutrient absorption. The corn crop develops stress symptoms due to lack of water earlier when it is infested by weeds than when it is weed free (Tollenaar *et al*., 1997). Nevertheless, there are no differences in water content in the profile of the soil for corn with or without weeds (Tollenaar *et al.,* 1997). In reality, water content in corn plots with weeds was greater than in the crop plots without weeds (Thomas & Allison, 1975). The development of water stress symptoms with the presence of weeds may not be caused by water availability, but by the reduced ability to absorb water through the root system. Therefore, despite the fact that the experiment on which this study was based used irrigation, the reduction in the corn root system caused by the weeds would reduce water absorption capacity. Water deficiency induces the closing of stomata thus paralyzing photosynthesis and drastically reducing production in corn competing with weeds (Silva *et al.,* 2004b). This problem is aggravated if there are C_4 weeds in the area, such as the *Cenchrus echinatus* L. that like corn, have high efficiency in water use (Silva *et al.,* 2004b). Another possibility would be the weed root exudates that could inhibit corn root growth (Rajcan & Swanton, 2001).

Two components are involved in the competition for light: the quantity and quality of light. The quantitative component of light determines photosynthetic activity, whereas the quality of light influences plant morphology. An important characteristic of corn is that most of the light is intercepted by the younger, more efficient leaves above the ear and less than 10% of the photon flux density (PFD) reaches the leaves below 1 m. On the other hand, most weeds are less than 1 m in height at blooming and after blooming. Thus, direct competition for PFD between corn and weeds is relatively small. Even in weed free crops, the leaves below the ear are in the shadows of the upper leaves and are older. Consequently, their photosynthetic rates are smaller than those of the upper leaves. That means that corn yield loss due to competition with weeds for PFD cannot be explained by the reduced photosynthetic rates of the lower leaves in the shadow of weeds. The leaf area index (LAI) defines the ability of a plant to intercept PFD and it is an important determining factor for the accumulation of dry matter. A high degree of competition with weeds was seen (Tollenaar *et al.,* 1994) to reduce corn LAI at blooming by 15%. Thus, grain yield loss resulting from competition for light is best explained through the reduction in LAI than in lower photosynthetic rates of shaded leaves (Rajcan & Swanton, 2001). Actually, in the experiment on which this study is based, a reduction was observed in the corn leaf area (Table 2), which agrees with other authors (Aflakpui *et al*., 2002), due to competition with weeds. Other authors (Ford & Pleasant, 1994) also verified a reduction in the number of corn leaves due to weeds.

It is interesting to mention that the reduction in leaf area (Table 2) should reduce shadows on weeds making them more aggressive towards corn, and therefore generating a vicious cycle for the crop: the weeds reduce the corn leaf area, and this reduction favors the growth of weeds, and so on.

The lower leaves are not only exposed to a reduced amount of PFD, but they also receive a

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

quality of light that differs from the total sunlight received by the upper leaves. The light within the crown is rich in far red radiation, FR (730 at 740 nm). This is caused by the selective absorption of red light, R (660-670 nm) by photosynthetic pigments and the reflection of FR light by green leaves. This makes the far-red/red (FR/R) ratio greater in the lower part of the crown than on the upper part of the crown. The FR/R ratio plays an important role in the induction of many morphological changes in plant architecture (lengthening of the stem, apical dominance, reduced branching, thinner leaves, leaf area distribution, etc.) (Salisbury & Ross, 1991). Consequently, plants that grow in FR rich light tend to have a different architecture than plants that grow in complete sunlight. Shaded plants tend to allocate more leaf area in the upper portion of the crown where more light is available, whereas plants grown in complete sunlight have a more pyramid-shaped leaf area distribution, which limits the shading of lower leaves by upper ones. Although, as mentioned before, weeds generally do not shade corn, there are indications that corn grown in the presence of weeds receives a greater FR/R ratio than the weed free crop (Rajcan & Swanton, 2001).

Conclusions

Only ten weed species were found in the experiment, many of which were gramineae. The cultivars only differed in grain yield when the weeds were controlled, with BA 8517 cultivar standing out as being superior. The cultivars AG 405, BA 9513, and EX 6005 are more competitive than AG 2060, BA 8517, and DKB 435 against weeds. The weeds reduced green ears yield besides 16 of the 26 evaluated characteristics, including some traits of the stalk, leaves, tassel, ear, and grain.

Literature Cited

AFLAKPUI, G. K. S.; GREGORY, P. J.; FROUD-WILLIAMS, R. J. Growth and biomass partitioning of maize during vegetative growth in response to *Striga hermonthica* infection and nitrogen supply. **Experimental Agriculture**, Cambridge, v. 38, n. 1, p. 265-276, 2002.

BEGNA, S. H., HAMILTON, R. I.; DWYER, L. M.; STEWART, D. W.; CLOUTIER, D.; ASSEMAT, L.; FOROUTAN-POUR, K.; SMITH, D .L. Morphology and yield response to weed pressure by corn hybrids differing in canopy architecture. **European Journal of Agronomy**, Montrouge, v. 14, n. 4, p. 293-302, 2001.

BUHLER, D. D. Weed population responses to weed control practices. I. Seed bank, weed populations, and crop yields. **Weed Science**, Champaign, v. 47, n. 4, p. 416-422, 1999.

CARMO FILHO, F. do; OLIVEIRA, O. F. de. **Mossoró**: um município do semi-árido nordestino. Mossoró: Fundação Guimarães Duque/ ESAM, 1989. 62 p. (Coleção Mossoroense, Série B, n. 672).

CARRUTHERS, K.; FE, Q.; CLOUTIER, D.; SMITH, D. L. Intercropping corn with soybean, lupin and forages: weed control by intercrops combined with interrow cultivation. **European Journal of Agronomy**, Montrouge, v. 8, n. 1, p. 225-238, 1998.

CATON, B. P.; COPE, A .E.; MORTIMER, M. Growth traits of diverse rice cultivars under severe competition: implications for screening for competitiveness. **Field Crops Research**, Amsterdam, v. 83, n. 1, p. 157-172, 2003.

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

FAO. **Soil map of the world**; revised legend. Rome: UNESCO, 1988. 119 p.

FORD, G. T.; PLEASANT, J. Competitive abilities of six corn (*Zea mays* L.) hybrids with four weed control practices. **Weed Technology**, Champaign, v. 8, n. 3, p. 124-128, 1995.

GOMES, J .K. de O. **Efeitos do controle de plantas daninhas, através da consorciação com o caupi, sobre a morfologia e o rendimento do milho.** 2005. 45 f. Dissertação (Mestrado) – Universidade Federal Rural do Semi-Árido, Mossoró.

JANNINK, J.-L; ORF, J. H.; JORDAN, N. R.; SHAW, R. G. Index selection for weed suppressive ability in soybean. **Crop Science**, Madison, v. 40, n. 6, p. 1087-1094, 2000.

JORDAN, N. Prospects for weed control through crop interference. **Ecological Applications**, Washington, v. 3, n. 1, p. 84-91, 1993.

LINDQUIST, J. L.; MORTENSEN, D. A. Tolerance and velvetleaf (*Abutilon theophrasti*) suppressive ability of two old and modern corn (*Zea mays*) hybrids. **Weed Science**, Champaign, v. 46, p. 569-574, 1998.

MENALLED, F. D.; GROSS, K. L.; HAMMOND, M. Weed aboveground and seedbank community responses to agricultural management systems. **Ecological Applications**, Washington, v. 11, n. 6, p.1586-1601, 2001.

PESTER, T. A.; BURNSIDE, O. C.; ORF, J. H. Increasing crop competitiveness to weeds through crop breeding. **Journal of Crop Production**, Binghamton, v. 2, n. 1, p. 59-76, 1999.

RAJCAN, I; SWANTON, C. J. Understanding maize-weed competition: resource competition, light quality and the whole plant. **Field Crops Research**, Amsterdam, v. 71, p. 139-150, 2001.
SALISBURY, F. B.; ROSS, C. W. **Plant physiology**. 4 ed. Belmont: Wadsworth, 1991. 459 p.

SILVA, P. S. L. e.; SILVA, E. S.; MESQUITA, S. S. X. Weed control and green ear yield in maize. **Planta Daninha**, Viçosa, v. 22, n. 1, p. 137-144, 2004a.

SILVA, A. A. da; VARGAS, L.; WERLANG, R. C. Manejo de plantas daninhas na cultura do milho. In: GALVÃO, J. C. C.; MIRANDA, G. V. **Tecnologias de produção de milho.** Viçosa, UFV, 2004b. p.269-310.

SINOQUET, H.; CALDWELL, R. M. Estimation of light capture and partitioning in intercropping systems.In: SINOQUET, H; CRUZ, P. (Ed.). **Ecophysiology of tropical intercropping**. Paris, INRA 1995. p. 79-80.

SISTEMA brasileiro de classificação de solos. Brasília: Embrapa Serviço de Produção da Informação; Rio de Janeiro: Embrapa Solos, 1999. 412 p.

SREENIVAS, G.; SATYANARAYANA, V. Nutrient removal by weeds and maize. **Indian Journal of Agronomy**, New Delhi, v. 41, n. 1, p. 160-162, 1996.

THOMAS, P .E L.; ALLISON, J. C. S. Competition between maize and *Rottboellia exaltata*. **Journal of Agricultural Science**, Cambridge, v. 84, n. 1, p. 305-312, 1975.

TOLLENAAR, M.; NISSANKA, S. P.; AGUILERA, A.; WEISE, S. F.; SWANTON, C. J.

http://dx.doi.org/10.18512/1980-6477/rbms.v6n1p74-83

Effects of weed interference and soil nitrogen on four maize hybrids. **Agronomy Journal**, Madison, v. 86, n. 2, p. 596-601, 1994.

TOLLENAAR, M.; AGUILERA, A.; NISSANKA, S. P. Grain yield is reduced more by weed interference in an old than in a new maize hybrid. **Agronomy Journal**, Madison, v. 89, n. 1, p. 239-246, 1997.

ZAR, J. H. **Biostatistical analysis**. 4.ed. Upper Saddle River: Prentice Hall, 1999. 663 p**.**